भारतीय मानक
Indian Standard

IS 17181 : 2020

स्टीम जनरेटर और हीट एक्सचेंजर ट्यूब का रिमोट फिल्ड एडी करेंट परिक्षण

Remote Field Eddy Current Testing of Steam Generator and Heat Exchanger Tubes

ICS 77.040.20

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March 2020 **Price Group 2**

Non-Destructive Testing Sectional Committee, MTD 21

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Non-Destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Remote field eddy current testing is generally used to evaluate the condition of the tubing towards its failure during service and also to generate baseline data.

This standard applies to application of the procedure on ferromagnetic tubes only of uniform cross section and chemical composition.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’.

Indian Standard

REMOTE FIELD EDDY CURRENT TESTING OF STEAM GENERATOR AND HEAT EXCHANGER TUBES

1 SCOPE

This standard prescribes the procedure to be followed during remote field eddy current testing of installed seamless ferromagnetic steam generator and heat exchanger tubes for baseline and service induced flaws. This procedure is intended for use on ferromagnetic tubes with outside diameters from 12 to 50 mm with wall thickness in the range of 0.75 to 3.5 mm. This procedure is applicable only to ferromagnetic tubes of uniform cross section and chemical composition.

2 PRINCIPLE OF TEST

Remote field eddy current testing uses separate exciter and receiver coils which are axially separated by 2 to 3 times the inner diameter (ID) of the tube. The electromagnetic field emitted by the exciter travels outwards through the tube wall, axially along the outside of the tube and back through the tube wall to the receiver coil. Flaw indications are observed when:

a) In thin-walled areas, the field arrives at the receiver with less attenuation and less time delay;
b) Flaws interrupt the lines of magnetic flux, which are aligned mainly axially; and
c) Flaws interrupt the eddy currents which flow mainly circumferentially.

A flaw at any point on the through-transmission path between the exciter and receiver coils can create a perturbation; thus the remote field eddy current testing has approximately equal sensitivity to flaw on the inner and outer walls of the tube.

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Exciter — A coil or element that generates a time-varying electromagnetic field, usually a coil energized with alternating current; also known as transmitter.

3.2 Receiver — One or more coils or elements used to sense or measure magnetic field; also known as detector.

3.3 Remote Field — Electromagnetic field which has been transmitted through the tube and is observable beyond the direct coupling field of the exciter.

3.4 Remote Field Testing — Non-destructive test method that measures changes in the remote field region to detect and characterise flaws.

3.5 End Effect — The field from the exciter is able to propagate around the end of a tube. A flaw indication may be obscured or distorted if the flaw or any active probe element is within approximately three tube diameters of the tube end.

3.6 Remote Field Probe — The single entity of exciter-receiver coil assembly.

3.7 Effective Depth of Penetration — The depth in a material at which the induced current intensity due to sinusoidal excitation practically reduces to zero is called the effective depth of penetration. In effect, the test system does not detect any flaw situated beyond the effective depth of penetration in the material.

4 SUMMARY OF PRACTICE

The purpose of remote field eddy current testing is to evaluate the condition of the tubing. The evaluation results may be used to assess the likelihood of tube failure during service and also to generate baseline data. The remote field eddy current testing data is collected by passing remote field probe through each tube. The electromagnetic field transmitted from the exciter to the receiver is affected by:

a) Flaws;
b) The dimensions and electromagnetic properties of the tube; and
c) Objects in and around the tube that are ferromagnetic or conductive.

Sensitivity of remote field eddy current system is verified using reference standard (*see* **6.1**). System sensitivity and settings are checked and recorded prior to and at regular intervals during the examination. Data and systems settings are recorded in a manner that allows archiving and later recall of all data and system settings for each tube. Interpretation and evaluation are carried out using one or more flaw characterization standards. The supplier generates a final report detailing the results of the examinations.

5 REMOTE FIELD EDDY CURRENT TESTING SYSTEM

5.1 Equipment

The electronic instrument shall be capable of creating alternating current source at a fixed or variable frequency appropriate for the tube material. It shall be capable of measuring the amplitude and phase lag of the induced voltage in the receiver coil for each frequency. The instrument shall display data in real time. Saturation of electronic components is a potential problem in remote field eddy current testing because signal amplitude increases rapidly with decreasing tube wall thickness. Data acquired in such conditions is not acceptable. The instrument settings shall be set as appropriate to achieve the minimum required sensitivity to flaws.

5.2 Recording Devices

Storage oscilloscopes in XY mode or two channel strip chart recorders or analog to digital converter (minimum two channels and 200 samples per second sampling rate) controlled through a personal computer can be used as recording and storage devices. Alarm or a marking system can also be used with the main equipment.

5.3 Probe Driving System

A mechanical system capable of driving the remote field eddy current probe at a constant speed inside the tube shall be used to avoid unwanted signals due to probe wobble. The driving system shall in no way damage the tubes being tested. Servo motor or stepper motor based driving systems can also be used for this purpose. Probe centering is recommended.

5.4 Probes

The remote field probes should be of largest practically achievable diameter for the tubes being examined, leaving clearance for debris, dents, changes in tube diameter, and other obstructions. The probes should be of an appropriate configuration and size for the tube being examined and for the type or types of flaws to be detected.

5.4.1 *Probe Configuration*

The receiver is typically placed two to three tube diameters from the exciter in a location where the remote field dominates the direct coupling field. Other probe configurations or designs may be used to optimize flaw detection. Reduction in inner diameter may require smaller diameter probe that is able to pass through the restriction. In the unrestricted sections, the sensitivity is likely to be limited by the smaller probe fill factor.

5.4.2 *Absolute Receiver*

Absolute receiver coils are commonly used to locate and size large volume flaws and gradual metal loss.

5.4.3 *Differential Receiver*

Differential receiver coils tend to maximize the response from small volume flaws and abrupt changes along the tube length, and are also commonly used to locate and size large volume flaws.

5.4.4 *Array Receiver*

Array receiver coils use a configuration of multiple sensing elements. Each element is sensitive to a discrete section of the tube circumference. The elements may be oriented with their axes aligned axially or radially with respect to the tube.

5.4.5 *Exciter and Receiver Configuration*

Probes may have multiple exciters and receivers in a variety of configurations. These configurations may reduce interference from support plates and other conductive objects.

6 TEST PROCEDURE

6.1 System Reference Standard

The reference standard used shall be of the same nominal dimensions, material type and grade, fabrication route and heat treatment as that of the tubes to be examined. Artificial standard defects shall be machined (or using EDM) with a tolerance levels of ± 10 percent of the specified values. Artificial flaws shall be well separated (3 times the tube OD) such that the signals due to them would not overlap with each other and also lie well above the end effect region. The reference standard contains the following artificial machined flaws.

6.1.1 *Through Hole (A)*

A through hole whose diameter is equal to the tube wall thickness multiplied by a specified factor F is used. For tubes of outside diameter less than 25 mm the factor is 2. For tubes of outside diameter greater than or equal to 25 mm the factor is 3.

6.1.2 *Short Circumferential Groove (B)*

A short circumferential groove of a depth of 10 percent of the wall thickness and axial length of 15 mm is used. Edges shall be straight (approximately 90°) with an angle not more than 105^{o} as shown in Fig. 1.

6.1.3 *Support Plates*

Support plates may be simulated by drilling a hole through a solid flat plate or circular plate of diameter equal to 5 times the outer diameter of the tube. The radial clearance between the support plate hole and

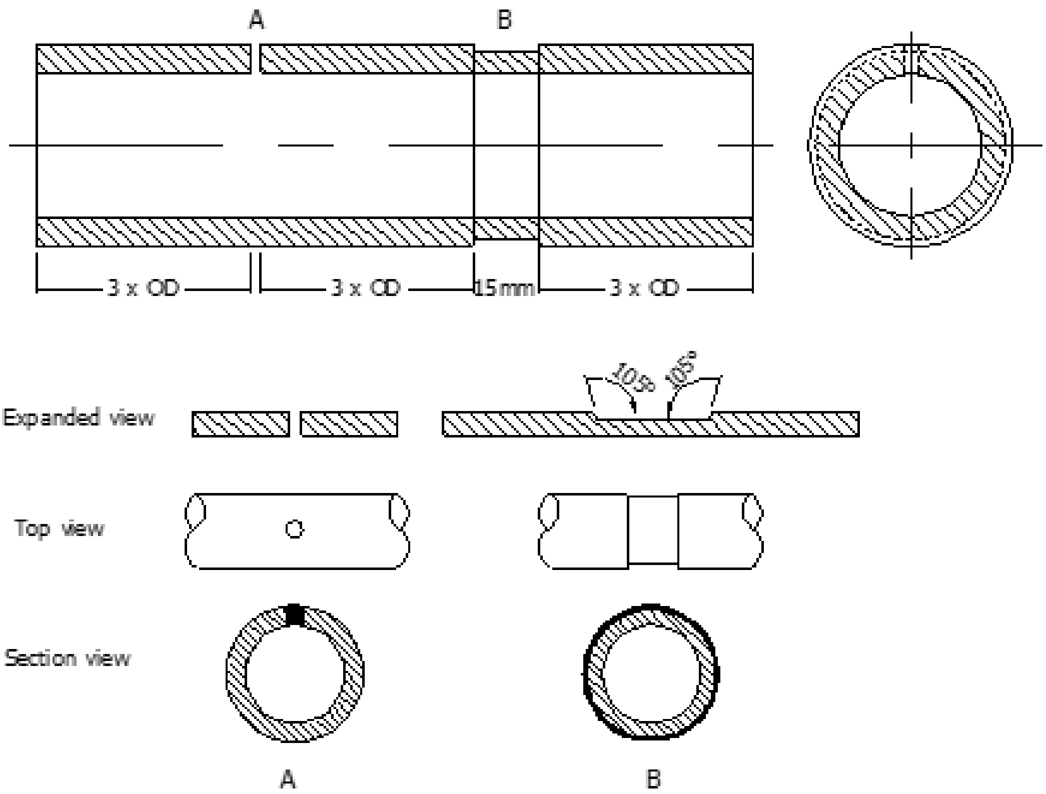

FIG. 1 REFERENCE STANDARD TO BE USED FOR REMOTE FIELD EDDY CURRENT TESTING

tube outer diameter shall be less than 1.0 mm.

6.2 Preparation

Cleaning of tubes prior to remote field testing is necessary to remove obstructions and heavy ferromagnetic or conductive debris.

6.3 Operating Frequency

The frequency of the instrument shall be optimized such that the effective depth of penetration is ensured and signals from reference flaws A and B in Fig. 1 are distinctly seen with maximum possible amplitude and phase angle separation with respect to ambient noise.

6.4 Pull Speed

Determine a pull speed appropriate to the frequency, sampling rate and required detection sensitivity. Maintain uniform pull speed during the testing of tubes.

6.5 Method of Testing

Ensure that the remote field testing system yields the minimum required sensitivity to all the system reference standard defects at the examination pull speed (*see* **6.4**).

For a flaw to be considered detectable, its indication should exceed the ambient noise by a factor of at least 3, unless and otherwise specified by the user. An exception may be made when the user requires only a large volume metal loss examination, in which case the sensitivity should be demonstrated for specified large volume flaws machined in a separate reference standard.

Insert the remote field probe into the tube and acquire data while pulling the probe at the optimized pull speed (*see* **6.4**). Maintain as uniform speed as possible throughout the examination to produce repeatable indications.

6.6 System Check

Carry out system check at regular intervals using the reference standard to verify working of remote field probe and to demonstrate system sensitivity and operating parameters to the satisfaction of the user. Carry out system check prior to starting the examination. System check shall be carried out at:

a) The beginning and end of each work shift;

b) When equipment function is in doubt;

c) After a change of inspection personnel;

d) After a change of any essential system components; and

e) Overall at a minimum of every four hours.

If flaw responses from the system reference standard are changed substantially, all the tubes examined since the last system check shall be reexamined. The remote field probe shall be replaced, if not working.

7 ACCEPTANCE STANDARD

The recording criteria and acceptance standard shall be subject to agreement between the contracting parties. All indications and flaws which are equal to or greater than the agreed values may be the cause for rejection.

8 REPORTING OF TEST RESULTS

The test report shall contain the following information:

a) Tube sheet lay out drawing reference number where applicable;

b) Material grade and tube dimensions;

c) Surface conditions of the tube before and after testing;

d) Make of the remote field instrument used for testing;

e) Remote field probe details such as dimensions (OD, ID), coil spacing;

f) Operating frequency and instrument settings;

g) Test speed or pull speed of the probe;

h) Approximate location of the flaw detected from a reference point, size and its extent in the axial direction;

j) Chart record or data where available;

k) Any unusual occurrence encountered during test; and

m) Personnel performing the examination and their qualifications and signatures.

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This Indian Standard has been developed from Doc No.: MTD 21 (10414).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi